Experimental Evaluation of Machinable Aspect Ratio in Micro Cutting of V-Grooves on Electroless Nickel Plated Die Materials

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Abstract

This study comprised a series of experimental evaluations conducted to determine the maximum achievable aspect ratio in microcutting V-shaped grooves, which is expected to play increasingly important roles in today's manufacturing technology, on electroless nickel plated die materials when using single-crystal diamond tools with point angles of 20°–80°.

1 Introduction

Micromechanical machining technology based on conventional cutting has advantages such as high productivity, low cost, and good finish. And it creates high-quality micropatterns on various materials with features ranging from a few inches to tens of inches across. Therefore, recently, there has been strong interest in fabricating micropatterns through mechanical cutting processes, i.e., ultra-precision machining [1].

With the continued demand for slimmer and brighter LCD panels of late, the role of LGP(Light Guide Plate) or optical films that produce diffuse, uniform light from the backlight unit (BLU) is becoming more important. LCD BLUs comprise various optical elements such as a LGP, diffuser sheet, prism sheet, and protector sheet with V-shaped grooves. The use of high aspect ratio grooves would reduce the number of sheets and enhance light efficiency, but there is the limit to the aspect ratio that can be achieved for a given material and cutting tool.

Studies have been conducted on the cutting performance of single-point diamond tools in face turning [2] and face grooving [3] on such dies. Most were related to the wear characteristics and none addressed the achievable aspect ratio. Therefore, in this study, a series of experimental evaluations were carried out to determine achievable aspect ratio in microcutting V-shaped grooves on electroless nickel plated die materials using single-crystal diamond tools with point angles of 20°–80°. Cutting performance was evaluated at various cutting speeds and depths of cut using different machining methods and machine tools.

2 Experiments

A Toshiba UMP-160160D ultra-precision machine was used for the experiments. The workpiece was a stainless steel substrate (STAVAX) with a 100-µm-thick coat of nickel. Single-crystal diamond tools with a tool point angle of 20°–80°, rake angle of 0°, and rake face crystal orientation along {110} were used, as shown in Fig 1. The depth of cut *h* was varied from 1 to 10 µm. The patterns were observed under a Keyence 3D violet laser scanning microscope at 18000× magnification and a resolution of 0.001 µm. They were also analyzed using a Panasonic UA3P profilometer.

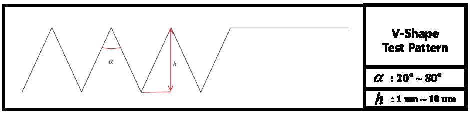

Figure 1: Test V-shaped groove pattern

3 Results and discussion

The shaping technique was applied to achieve V-shaped grooves of different heights and angles by altering the pitch, depth of cut, and tool point angle. Each pattern was observed under a digital microscope to investigate the machinability. Fig. 2 shows the results obtained when using a feed rate of 3000 mm/min and a pattern angle α of 20°–60°.

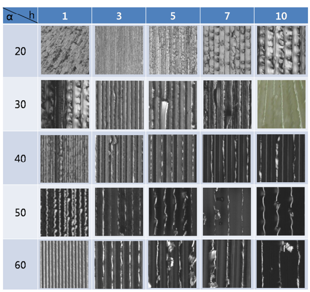

Figure 2: Machining results at sharp angles

Fig. 2 shows that it is very difficult to produce sharp (≤60°) V-shaped grooves since plastic deformation and burring easily occur. The cutting force perpendicular to the feed direction causes deformation of the edges, which are weakly supported because of high aspect ratio. V-shaped grooves with relatively large angles of 70° and 80° were also produced (Fig. 3).

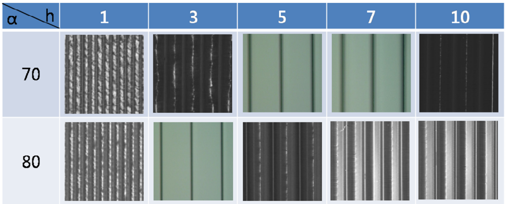

Figure 3: Machining results at 70° and 80°

Fig. 3 shows that angles of ≥70° can be used without edge deformation or burrs. However, it is not easy to clearly set the lower limit for the achievable feature size with only the microscopy image. Additionally 1- and 3–μm-high machined pattern profiles that have ambiguity to decide the machinability were measured using UA3P. The results show that only the 5-μm–high, 70° and 3-μm–high, 80° pattern did not show similar phenomenon such as plastic deformation or burrs. It is judged that the resistance offered to the cutting forces is weak because of the short base length of the patterns. That is, shallow micropatterns are more difficult to produce for the same aspect ratio. To summarize, the cutting parameters that produce acceptable V-shaped grooves are illustrated in Fig. 4.

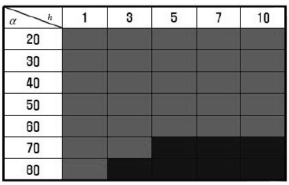

Figure 4: Acceptable region (dark gray color) for V-shaped grooves

4 Conclusions

This study investigated the maximum achievable aspect ratio for V-shaped microgrooves, which usually used in optical parts such as BLUs and optical films in LCD panels. Cutting experiments on electroless nickel plated die materials using single-crystal diamond tools with point angles of 20°–80° were carried out to evaluate the cutting performance under various cutting conditions and using different methods. The experimental results pertinent to optical designers and machinists are that V-shaped patterns with angles≥80° can be realized regardless of the machining conditions and equipment.

Acknowledgments

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